US009122939B2

(12) **United States Patent**
Gao et al.

(10) **Patent No.: US 9,122,939 B2**
(45) **Date of Patent: Sep. 1, 2015**

(54) **SYSTEM AND METHOD FOR READING OPTICAL CODES ON REFLECTIVE SURFACES WHILE MINIMIZING FLICKER PERCEPTION OF PULSED ILLUMINATION**

(75) Inventors: **WenLiang Gao**, Eugene, OR (US); **Craig D. Cherry**, Eugene, OR (US)

(73) Assignee: **Datalogic ADC, Inc.**, Eugene, OR (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 584 days.

(21) Appl. No.: **13/204,627**

(22) Filed: **Aug. 5, 2011**

(65) **Prior Publication Data**

US 2012/0067956 A1 Mar. 22, 2012

Related U.S. Application Data

(60) Provisional application No. 61/383,694, filed on Sep. 16, 2010.

(51) **Int. Cl.**
G06K 7/10 (2006.01)

(52) **U.S. Cl.**
CPC ***G06K 7/10792*** (2013.01); ***G06K 7/1095*** (2013.01)

(58) **Field of Classification Search**
USPC 235/472.01
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,315,245	A	2/1982	Nakahara et al.	
4,930,884	A	6/1990	Tichenor	
4,949,391	A	8/1990	Faulkerson et al.	
4,969,034	A	11/1990	Salvati	
5,010,241	A	4/1991	Butterworth	
5,130,856	A	7/1992	Tichenor	
5,245,168	A	9/1993	Shigeta	
5,475,207	A	12/1995	Bobba	
5,572,006	A	11/1996	Wang et al.	
5,585,616	A	12/1996	Roxby et al.	
5,705,802	A	1/1998	Bobba	
5,723,868	A	3/1998	Hammond	
5,756,981	A *	5/1998	Roustaei et al.	235/462.42
5,837,988	A	11/1998	Bobba	
5,936,218	A	8/1999	Ohkawa	
6,061,091	A	5/2000	Van de Poel et al.	
6,065,678	A	5/2000	Li et al.	
6,189,795	B1	2/2001	Ohkawa	

(Continued)

FOREIGN PATENT DOCUMENTS

KR	10-2007-0063899 A	6/2007
KR	10-2009-0110245	10/2009

OTHER PUBLICATIONS

Hensel Jr., "Cell phone boarding passes going into use here first," http://www.chron.com/disp/story.mpl/front/5349969.html, visited Feb. 19, 2010.

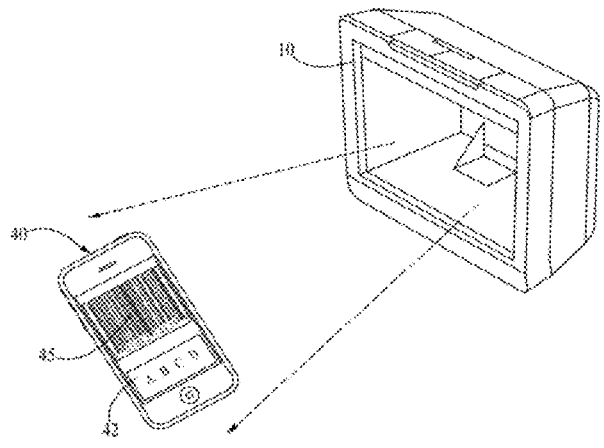
(Continued)

Primary Examiner — Rafferty Kelly
(74) *Attorney, Agent, or Firm* — Stoel Rives LLP

(57) **ABSTRACT**

Methods and systems are disclosed for improved operation of readers of optical codes presented on electronic display screens or other highly reflective surfaces. Certain configurations include controlling image exposure and illumination pulse timing so as to avoid or minimize the perception of flicker of the pulsed illumination by a user or bystander while implementing methods for reading optical codes presented on electronic display screens or other highly reflective surfaces.

20 Claims, 6 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,254,003	B1	7/2001	Pettinelli et al.	
6,290,135	B1	9/2001	Acosta	
6,318,635	B1	11/2001	Stoner	
6,347,163	B2	2/2002	Roustaei	
6,462,880	B1	10/2002	Ohkawa	
6,505,778	B1	1/2003	Reddersen et al.	
6,568,598	B1	5/2003	Bobba	
6,609,660	B1	8/2003	Stoner	
6,631,844	B1	10/2003	Ohkawa	
6,708,883	B2	3/2004	Krichever	
6,749,120	B2	6/2004	Hung et al.	
6,783,068	B2	8/2004	Hecht	
6,825,486	B1	11/2004	Cole et al.	
6,974,084	B2	12/2005	Bobba	
6,980,692	B2	12/2005	Chamberlain	
6,991,169	B2	1/2006	Bobba	
7,131,587	B2 *	11/2006	He et al.	235/454
7,147,159	B2	12/2006	Longacre, Jr. et al.	
7,172,125	B2	2/2007	Wang et al.	
7,178,734	B1	2/2007	Hammer	
7,198,195	B2	4/2007	Bobba	
7,204,420	B2	4/2007	Barkan et al.	
7,212,279	B1	5/2007	Feng	
7,234,641	B2	6/2007	Olmstead	
7,290,711	B2	11/2007	Barkan	
7,296,744	B2	11/2007	He	
7,398,927	B2	7/2008	Olmstead et al.	
7,461,790	B2	12/2008	McQueen et al.	
7,475,821	B2	1/2009	Barkan et al.	
7,490,770	B2	2/2009	Shearin	
7,490,776	B2	2/2009	Thuries	
7,494,065	B2	2/2009	Barkan et al.	
7,527,207	B2	5/2009	Acosta et al.	
7,546,951	B2	6/2009	Kotlarsky et al.	
7,568,623	B2	8/2009	Retter et al.	
2002/0067850	A1	6/2002	Williams et al.	
2002/0070278	A1 *	6/2002	Hung et al.	235/472.01
2003/0098352	A1	5/2003	Schnee et al.	
2003/0230630	A1	12/2003	Whipple et al.	
2004/0179254	A1	9/2004	Lewis et al.	
2004/0246367	A1	12/2004	Yoshida	
2005/0253937	A1	11/2005	Moholt et al.	
2006/0255150	A1	11/2006	Longacre, Jr.	
2007/0001015	A1	1/2007	Suzuki et al.	
2007/0034696	A1	2/2007	Barkan et al.	
2007/0035718	A1	2/2007	Haddad	
2007/0040034	A1	2/2007	Hennick et al.	
2008/0035732	A1	2/2008	Vinogradov et al.	
2008/0035733	A1	2/2008	Vinogradov et al.	
2008/0080785	A1	4/2008	Ford	
2008/0099561	A1	5/2008	Douma	
2008/0191022	A1	8/2008	Barkan et al.	
2009/0001166	A1	1/2009	Barkan et al.	
2009/0001168	A1	1/2009	Hammer	
2009/0057412	A1	3/2009	Bhella et al.	
2009/0108076	A1	4/2009	Barkan et al.	
2010/0219249	A1	9/2010	Barkan	
2012/0000982	A1	1/2012	Gao	
2012/0018516	A1	1/2012	Gao	

OTHER PUBLICATIONS

Reardon, "Cell phone as boarding pass," http://news.cnet.com/8301-10784_3-9896859-7.html, visited Feb. 19, 2010.

Tsa Blog, "TSA Paperless Boarding Pass Pilot Expanding," http://www.tsa.gov/blog/2009/06/tsa-paperless-boarding$_{13}$ -pass-pilot.html, visited Feb. 19, 2010.

Mobile Commerce Daily, "Hexaware launches 2D bar code boarding pass service," http://www.mobilecommercedaily.com/2009/11/30/hexaware-launches-2d-bar-code-boarding-pass-service , visited Feb. 19, 2010.

American Airlines, "Introducing Mobile Boarding Passes," http://www.aa.com/i_18n/urls/mobileBoarding.jsp, visited Feb. 19, 2010.

International Patent Application No. PCT/US2011/049556, International Search Report and Written Opinion, Feb. 9, 2012, 8 pages.

* cited by examiner

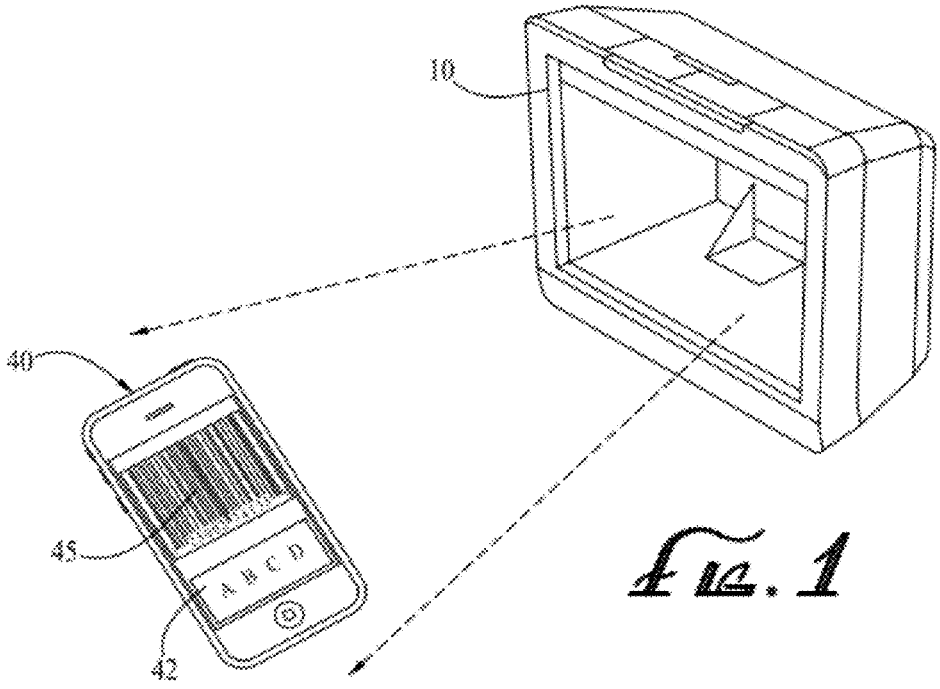


Fig. 1

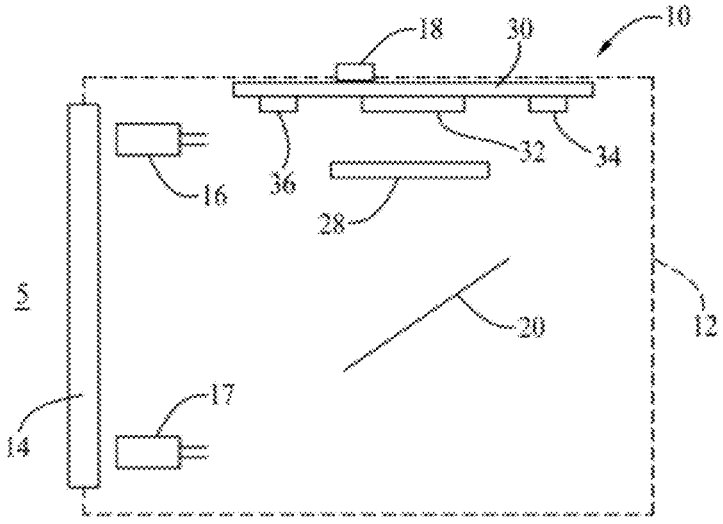


Fig. 2

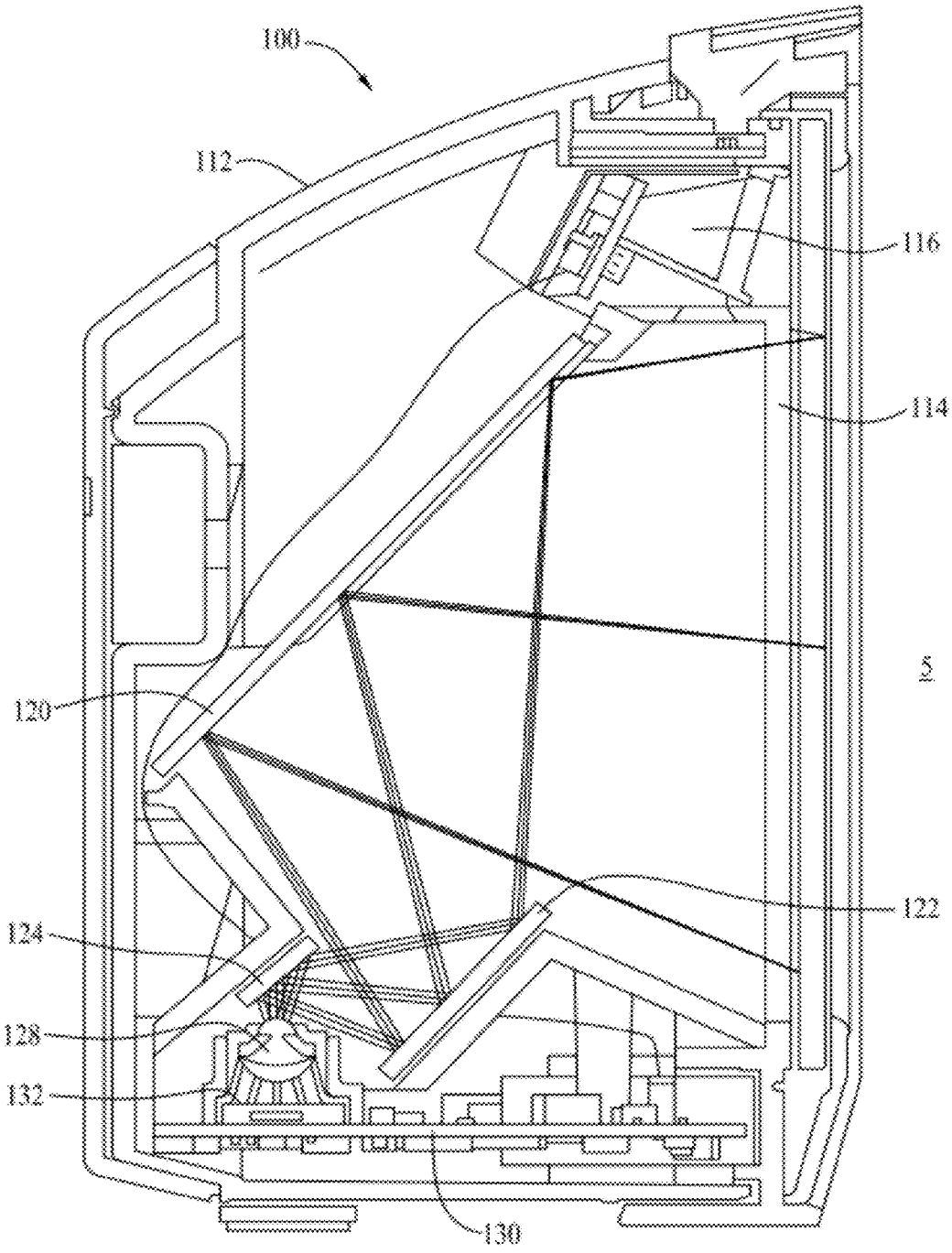


FIG. 3

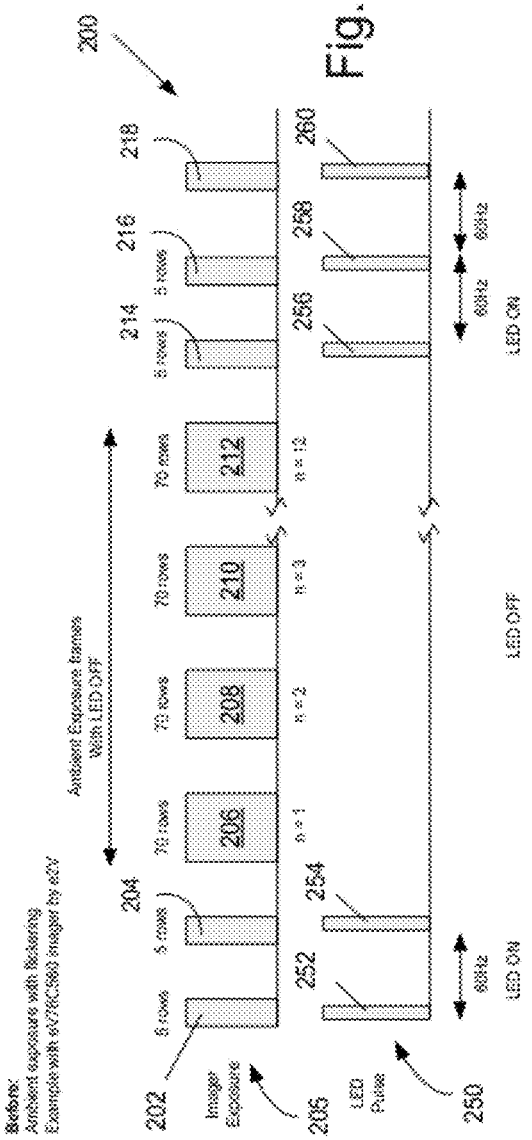

Before:
Ambient exposure with flickering
Example with oV7740/5680 images by oDV
200
Ambient Exposure frames
With LED OFF
202
204
205
206
208
210
212
214
216
218
250
252
254
256
258
260
Image Exposure
LED Pulse
LED OFF
LED ON
60Hz
n = 1
n = 2
n = 3
n = 10
5 rows
70 rows

Fig. 4

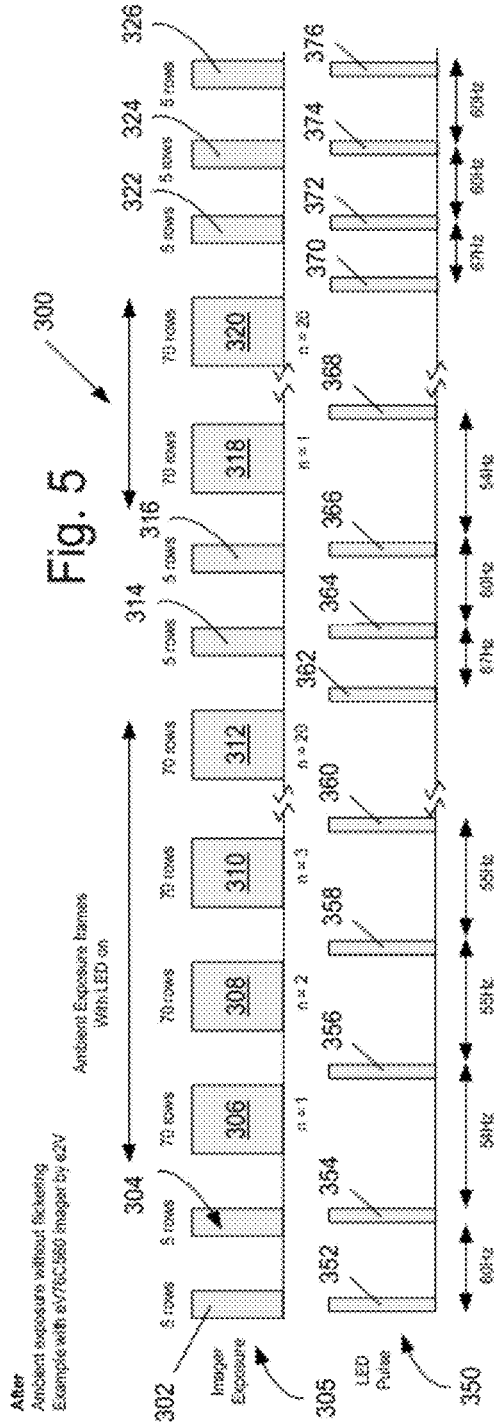

After
Ambient exposure without flickering
Example with oV7740/5680 images by oDV
300
Ambient Exposure frames
With LED on
302
304
305
306
308
310
312
314
316
318
320
322
324
326
350
352
354
356
358
360
362
364
366
368
370
372
374
376
Image Exposure
LED Pulse
60Hz
65Hz
67Hz
54Hz
n = 1
n = 2
n = 3
n = 20
5 rows
70 rows

Fig. 5

Fig. 6

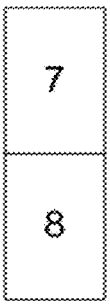
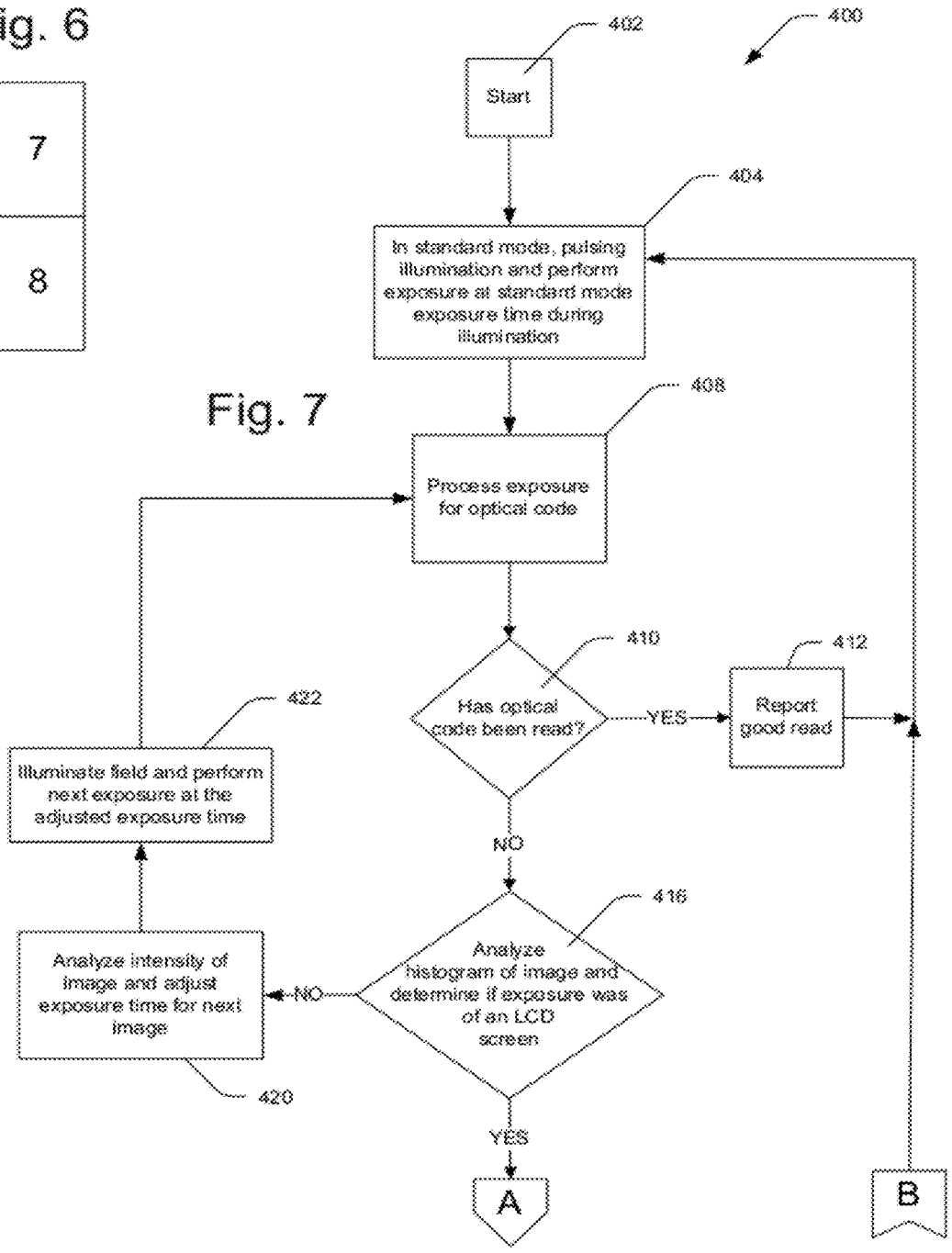

7
8

Fig. 7


400
402
Start
404
In standard mode, pulsing illumination and perform exposure at standard mode exposure time during illumination
408
Process exposure for optical code
410
Has optical code been read?
YES
412
Report good read
NO
416
Analyze histogram of image and determine if exposure was of an LCD screen
NO
Analyze intensity of image and adjust exposure time for next image
420
422
Illuminate field and perform next exposure at the adjusted exposure time
YES
A
B

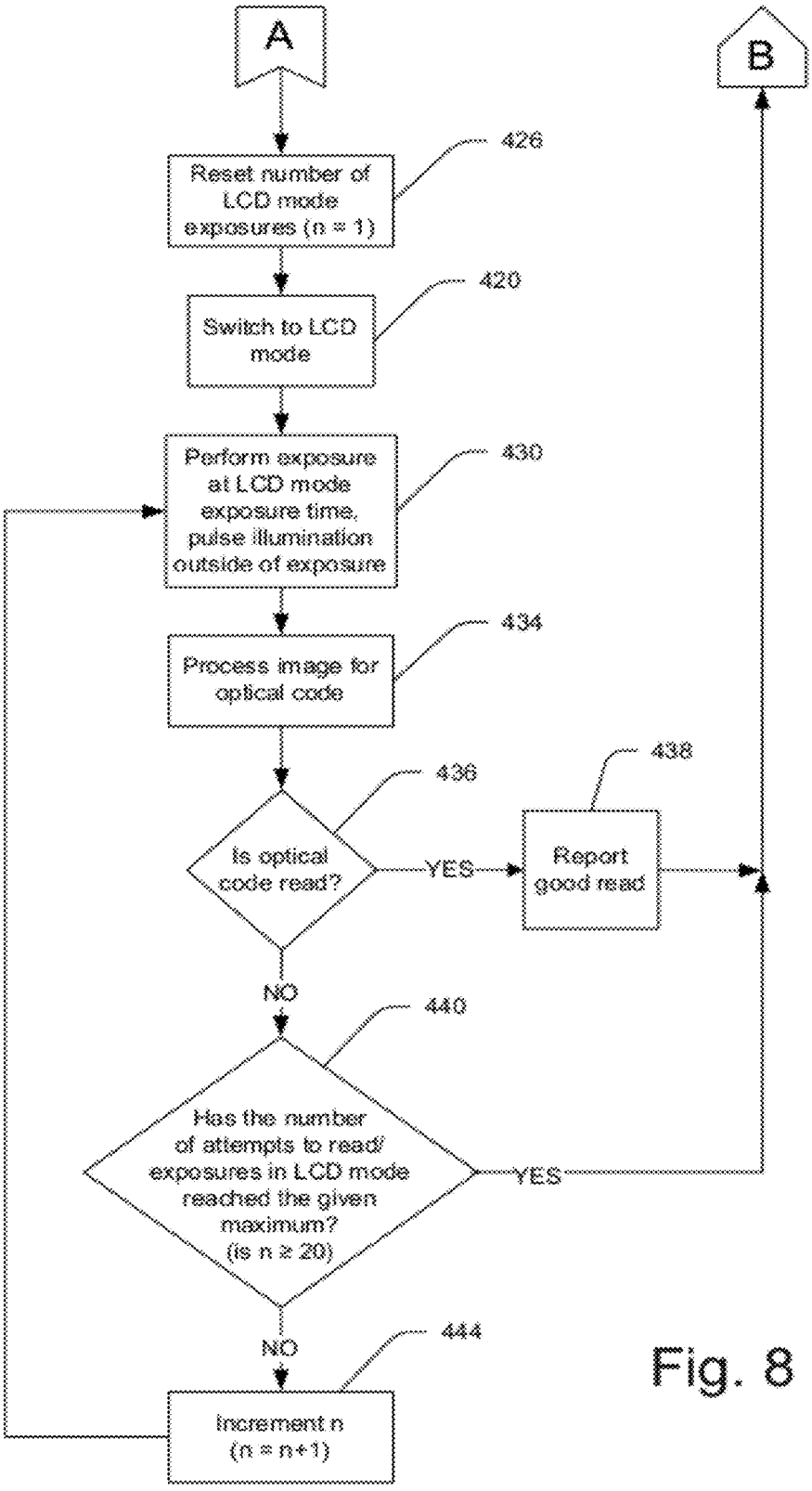
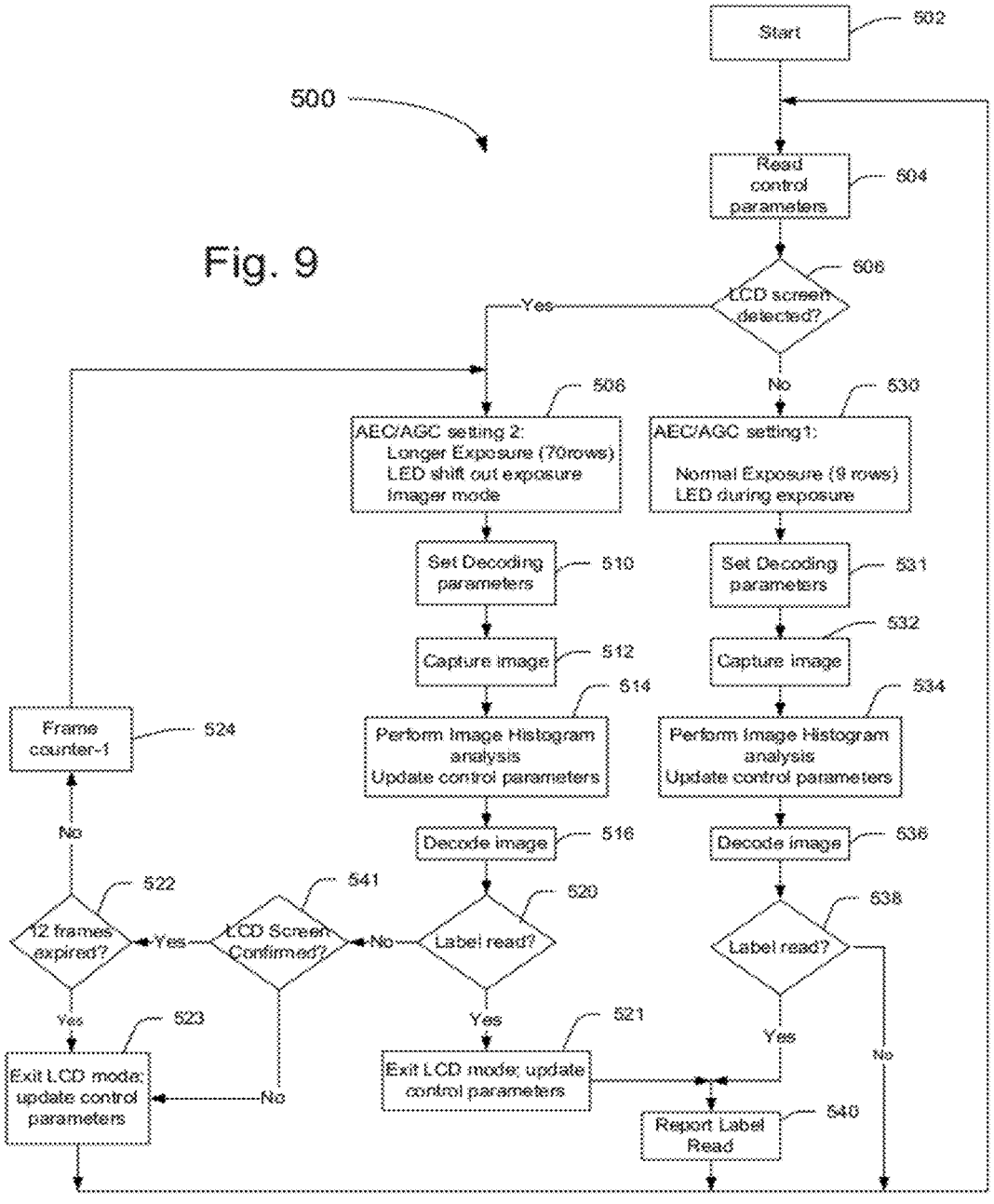

A
B
426
Reset number of LCD mode exposures (n = 1)
420
Switch to LCD mode
430
Perform exposure at LCD mode exposure time, pulse illumination outside of exposure
434
Process image for optical code
436
Is optical code read?
YES
438
Report good read
NO
440
Has the number of attempts to read/ exposures in LCD mode reached the given maximum? (is n ≥ 20)
YES
NO
444
Increment n (n = n+1)

Fig. 8

Fig. 9



AEC/AGC: Automatic Exposure Control/ Automatic Gain Control

SYSTEM AND METHOD FOR READING OPTICAL CODES ON REFLECTIVE SURFACES WHILE MINIMIZING FLICKER PERCEPTION OF PULSED ILLUMINATION

RELATED APPLICATION DATA

This application claims priority to U.S. provisional application No. 61/383,694 filed Sep. 16, 2010, hereby incorporated by reference.

BACKGROUND

Optical codes, such as barcodes and other machine-readable indicia, appear in various places in a variety of applications. There are a variety of such optical codes, including: linear barcodes (e.g., UPC code), 2D codes including stacked barcodes (e.g., PDF-417 code), and matrix codes (e.g., Datamatrix code, QR code, or Maxicode).

There are several types of data readers used for reading these optical codes. The most common types of optical code readers are laser scanners and imaging readers. A laser scanner typically moves, i.e. scans, a laser light beam across the barcode. Imaging readers are typically used to capture a 2D image of an area, including the optical code or other scene, focused onto a detector array such as charge-coupled devices (CCDs) and complementary metal oxide semiconductor (CMOS) imagers. With some such imaging readers, it may be advantageous to provide a source of illumination that illuminates the optical code or other scene being imaged, to provide the required signal response in the imaging device. Such a source of illumination can reduce exposure time, thereby improving imager performance, especially in low ambient light conditions and when imaging moving items.

Businesses have begun sending optical codes to customers who display such optical codes on a portable electronic device, such as a mobile telephone, personal digital assistant, palm, tablet, or laptop computer, or other suitable device having an electronic display, such as a liquid crystal display (LCD). For example, an airline passenger may display an optical code on a portable electronic device for an airline employee to read using a data reader as verification of the passenger's ticket. In another application, a customer in a store may display an optical code on a portable electronic device for a cashier to read using a data reader to redeem a coupon. Optical codes are also included on other items having highly, or relatively highly, reflective surfaces, for example, but not limited to, identification (ID) cards, aluminum cans, and objects in plastic packaging.

Optical codes presented on, or under a highly or relatively highly reflective surface are typically difficult to decode using general-purpose data readers. In one solution to better read optical codes on LCD displays, the reader is cycled between reading modes, a first mode having the LED illumination on to illuminate the surface, and a second mode having the LED illumination off to avoid specular reflection.

Switching between the illumination and non-illumination modes results in the LED illumination to be cycled on and off producing an annoying/distracting light flickering as perceived by the user or bystander. For most people, light pulsed at a frequency in excess of 50 Hz will exceed their so-called "flicker fusion frequency" and no flicker effect will be perceived. The flicker fusion frequency of human vision typically ranges from as low as about 15 Hz to as high as about 65 Hz. To avoid flicker fusion, U.S. Pat. No. 7,234,641 discloses pulsing the light at a sufficiently high frequency (e.g., in excess of 50 Hz) to avoid the flicker effect.

The present inventors have, therefore, recognized a need for improved methods of pulsing illumination for a data reader. The present inventor has also recognized a need for methods of pulsing illumination in conjunction with operating an imaging reader, particularly methods for electronic display screens reading that avoid the flicker effect.

SUMMARY

Methods and systems are disclosed for improved operation of readers of optical codes presented on electronic display screens or other highly reflective surfaces.

In certain embodiments, systems and methods of pulsing one or more sources of illumination are disclosed for avoiding or minimizing the perception of illumination flicker by a user or bystander while implementing methods for reading optical codes presented on electronic display screens or other highly reflective surfaces.

Additional aspects and advantages will be apparent from the following detailed description of preferred embodiments, which proceeds with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** schematically illustrates a data reader reading an optical code displayed on an electronic display screen of an electronic device.

FIG. **2** is a diagrammatic view of a data reader according to a preferred embodiment.

FIG. **3** is a diagrammatic view of a data reader according to another preferred embodiment.

FIG. **4** is a timing diagram illustrating relative timing of imager frame exposure and illumination pulses with a fixed pulse rate illumination.

FIG. **5** is a timing diagram illustrating relative timing of imager frame exposure and illumination pulses, in accordance with a preferred embodiment.

FIG. **6** (comprising FIGS. **7** and **8**) is a flow chart of a method for data reading of an optical code being displayed on an electronic display according to a preferred embodiment.

FIG. **9** is a flow chart of a program algorithm for data reading of an optical code being displayed on an electronic display according to another embodiment.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The described features, structures, characteristics, and methods may be combined in any suitable manner in one or more embodiments. In view of the disclosure herein, those skilled in the art will recognize that the various embodiments can be practiced without one or more of the specific details or with other methods, components, materials, or the like. In other instances, well-known structures, materials, or operations are not shown or not described in detail to avoid obscuring aspects of the embodiments. For convenience, the methods and systems may be described herein with reference to barcodes or other optical codes, however, it is understood that the methods described herein are applicable to any host computer and to any type of optically readable code, such as, but not limited to, those described above, fingerprints, and other suitable codes.

FIG. **1** is a diagrammatic view of a data reader **10** in accordance with a first embodiment shown reading a barcode **45** displayed on the display screen **42** of a pda (personal digital assistant) or cell phone **40** (a smartphone being illus-

trated). The data reader **10** is illustrated as a Magellan® 3200VSi model bar code reader available from Datalogic of Eugene Oreg. (U.S.A.), but any suitable imaging reader may be employed. The data reader **10** is schematically depicted as a presentation scanner suitable for reading optical codes, symbols, or other items. The data reader **10** is illustrated, by way of example, as a single window reader with a vertically-oriented window **14**. The reader **10** may configured as a fixed unit (mountable to a support surface or free standing on a horizontal surface) or a handheld unit. The reader **10** may alternately be configured as a combined handheld/fixed unit, e.g., one that may rest/be self-supporting upon a horizontal surface but be grasped by the user and moved to aim toward an item to be read.

FIG. **2** is a diagram illustrating elements of the data reader **10** according to a first embodiment. The data reader **10** has a housing **12** with a front window **14** and one or more illumination sources **16**, **17** (the reader **10** showing an upper LED array **16** and a lower LED array **17**) for illuminating the read region **5** in front of the window **14**. An image of the field of view **5** is reflected by a mirror **20** upwardly (or downwardly depending on the reader configuration) where it is focused by focusing optics **28** onto an imaging array **32**. The imaging array thus acquires a two-dimensional (2D) image of the field of view **5**, converting the 2D image into an electronic signal (i.e., pixel data). The imaging array **32** is shown mounted on a printed circuit board **30** disposed on the bottom of the reader housing **12**. Preferably, the data reader **10** may include on-board memory **36** and a controller or imager processor **34** (also mounted on PCB **30**) for controlling operation of the imager **32** and other reader components.

FIG. **3** is a diagram illustrating elements of another data reader **100** similar to the reader **10** of FIG. **2**. The data reader **100** has a housing **112** with a front window **114** and one or more illumination sources **116** for illuminating the read region **5** in front of the window **114**. An image of the field of view **5** is reflected by a first mirror **120** downwardly to a second mirror **122**, sidewardly to a third mirror **124** and then downwardly where it is focused by focusing optics **128** onto an imaging array **132** that acquires a 2D image of the field of view **5**. The imaging array **132** is shown mounted on a printed circuit board **130** disposed on the bottom of the reader housing **112**. Preferably, the data reader **100** includes a controller or imager processor **134** (also mounted on PCB **130**) for controlling operation of the imager **132** and other reader components.

Other reader configurations may be employed such as those disclosed in U.S. application Ser. No. 13/188,244, hereby incorporated by reference, as well as any other suitable configuration.

In any of a mounted, hands-free, or hand-held mode, data reading may be activated by a suitable process such as for example (1) actuation of the trigger or switch **18**, (2) automatically by the processor **34** detecting the presence of an item within a scan volume in front of window **14**, or (3) by always being in a capture and decode images mode as long as the data reader **10** is in a scanning mode. An optical code such as code **45** on the electronic display screen **42** (or other surface) or other item may be read by presenting the item bearing the optical code into the read region in front of the window **14**.

The following description will be made with reference to data reader **10** but shall be understood as being similarly applicable to reader **100**. The data reader **10** preferably comprises an imager **32** such as a complementary metal oxide semiconductor (CMOS) imager. Alternately, a charged couple device (CCD) or other suitable imager may be used. The imager **32**, alone or together with logic components such as a complex programmable logic device (CPLD) or a field-programmable gate array (FPGA), is coupled to the processor **34**, which, among other functions, is preferably programmed to control operating parameters of the data reader **10** as discussed in detail below. Processor **34** is also preferably programmed to read and decode optical codes or other symbols or imaged items. The imager **32** may comprise a model eV76C560 imager by available from e2v Ltd. of Chelmsford, United Kingdom. Alternately, the imager may comprise an active-pixel imaging CMOS sensor with a global shutter, such as a model MT9V022 sensor sold by Micron Technology, Inc. of Boise, Id., USA, or may operate on a rolling basis.

The processor **34** may comprise any suitable digital processor, such as a low-power DSP core or ARM core processor. In preferred embodiments, processor **34** comprises an ARM9 processor AT91 SAM9G20 sold by Atmel of San Jose, Calif., USA, or OMAP processor sold by Texas Instruments of Dallas, Tex., USA or an i.MX1 series processor (such as the MC9328MX1 processor) sold by Freescale Semiconductor, Inc. of Austin, Tex., USA. Alternately, multiple processors or sub-processors or other types of processor electronics such as comparators or other specific function circuits may be used alone or in combination. For the purposes of this description, the term processor is meant to include any of these combinations.

The illumination source **16**/**17** preferably comprises a collection of LEDs, for example, infrared or visible spectrum LEDs, but may alternatively comprise another suitable light source, such as a lamp or laser diode. Each LED array may comprise one or more LEDs. As an example, the upper LED array **16** may comprise four LEDs arranged in a line at the top of the reader and the lower LED array **17** may similarly comprise four LEDs arranged in a line at the bottom of the reader. The illumination sources **16**/**17** may be coupled to and controlled by the processor **34**, or may be remotely mounted and powered. A power supply circuit is preferably provided for energizing the LEDs. The reader **100** for example may have two LED arrays, one of the arrays **116** being at the top left side of the housing **112** and the other at the top right side.

System electronics may also include a memory **36** (e.g., mounted on PCB **30**), such as a flash memory, random access memory, or other suitable memory, communicates with processor **34**. Alternately, memory **36** may be integrated with the processor **34**.

The controller or processor **34** is programmed to analyze an image scene to determine whether it is advantageous to change one or more operating parameters of the data reader **10**. Such image analysis could occur for every frame captured by an imager **32**, or alternately, may not occur for every frame, for example, image analysis may occur on a periodic basis.

In one mode of operating to capture and decode an optical code, the data reader **10** is activated, preferably by processor **34** detecting an item, such as electronic display **42** on the device **40**, within a read volume **5** or by activation of trigger **18**, to capture a first set of images of the item bearing an optical code, such as optical code **45**. The first set of images may include only one image, but preferably includes two or more images. Alternately, data reader **10** may continuously be on, i.e., operate or scan continuously.

In order to improve reading of the reflective surfaces of a display screen **42** depicting the barcode **45**, it is desirable for the reader to enter a specialized reading mode with the illumination turned off. There are various methods for the data reader **10** to detect that a display screen is in the read region such as disclosed in U.S. application Ser. No. 13/106,659

hereby incorporated by reference. One such method will be described, but any suitable method may be employed.

An imaging array **32** such as the model eV76C560 imager by e2v requires an image of a field of view and outputs a signal indicating a light intensity value as absorbed at the pixel. For an 8-bit value imager, the intensity value range is from 0 to 255, 0 being a no light or dark body condition (minimum intensity) and 255 being a saturated condition (maximum intensity). In between there is a relatively gray scale value for the pixel. For a 10-bit value imager, the pixel value ranges from 0 to 1024. The imager also outputs a histogram of how many pixels are of a particular pixel value range. The histogram can be calculated by using all or partial pixels of image for imagers that do not output histogram data.

When attempting to read a barcode displayed by an LCD or other display screen, there tends to be a large number of pixels having saturated or high intensity pixel values (V_{HIGH} or higher) due to the reflective nature of the display screen, while at the same time there is a large number of pixels with very low intensity pixel values (V_{LOW} or lower) for the same reasons. By taking a histogram of the output, it can be determined that if an image capture shows a certain large number of shiny (saturated or near saturated) pixels (i.e., pixels of high intensity value V_{HIGH} or higher) and a relatively large number of dark pixels (i.e., pixels of low intensity value V_{LOW} or lower) then it is concluded that the image is an LCD screen and the processor is switched to the LCD screen reading mode. To provide a few more examples, the preferred system may have these threshold values, V_{HIGH} and V_{LOW}, set by any number of methods, including (1) the values may be preset; (2) the values may be programmable values, selected by the user or by the technician selecting the values preferred for the particular establishment lighting conditions or the types of LCD screens being read; or (3) the values may selectable according to a self-learning program/algorithm such as the system remembering the values that it used when switching to cell phone mode and then using those values. The following is an example by which LCD screen indication can be made.

Example A—Condition 1: a certain number of pixels, for example 100 pixels (0.7%) having greater than a given/selected high intensity value (example intensity value V_{HIGH}=200 or higher); and Condition 2: a large percentage (example 70%) of pixels are below a low intensity value (example intensity value V_{LOW}=50 or lower). These values are for an 8-bit value imager having a range of 0-255.

If both conditions 1 and 2 above are satisfied (i.e., both the shiny pixel percentage and the dark pixel percentage are above the specific threshold percentage ranges), then it is assumed that an LCD screen has been read.

Another way of describing this method of LCD screen presence is by analyzing image histogram to determine whether the histogram is bi-modal, i.e., exhibits two peaks, or more than two peaks. One exemplary manner for analyzing the histogram includes using, or establishing, a low threshold and a high threshold. Preferably the low threshold corresponds to a number representing a range of dark, or relatively dark, pixels (low to relatively low grayscale) and the high threshold corresponds to a number representing a range of saturated, or relatively saturated, pixels (high to relatively high grayscale).

For example, an imager that captures eight bit image data preferably includes a grayscale ranging from 0 to 255, where 0 corresponds to dark pixels, (i.e., pixels receiving no, or almost no light), and 255 corresponds to saturated pixels, (i.e., pixels receiving so much light that a pixel registers a white portion of an image, even when the corresponding part of the item imaged by such a pixel is not white). In one embodiment for an eight bit imager, a low threshold may include only pixels registering 0 on the grayscale and a high threshold may include only pixels registering 255 on the grayscale. Alternately, a low threshold may include pixels in a dark-end range on the grayscale, such as 0 to 10, 0 to 20, 0 to 30, 0 to 40, 0 to 50, 0 to 60, or other suitable range, and a high threshold may include pixels in a light-end range on the grayscale, such as 200 to 255, 210 to 255, 220 to 255, 230 to 255, 240 to 255, or other suitable range.

The processor preferably determines whether a first predetermined percentage of pixels fall within the low threshold and whether a second predetermined percentage of pixels fall within the high threshold. For example, processor preferably obtains or calculates a first number of pixels where each pixel has a grayscale value in the low threshold, such as 0 to 75, for example. The processor preferably also obtains or calculates a second number of pixels where each pixel has a grayscale value in the high threshold, such as 235 to 255, for example. The processor next determines whether the first number of pixels is greater than the first predetermined percentage of pixels and whether the second number of pixels is greater than the second predetermined percentage of pixels. In one embodiment, for an imager having 360,960 pixels (a 752×480 pixel grid), a low threshold of 0 to 75 the first predetermined percentage of pixels is 40% of the imager's total number of pixels and for a high threshold of 230 to 255 the second predetermined percentage of pixels is 8% of the imager's total number of pixels. Other suitable percentages may be used for the same low and high thresholds. Alternately, other suitable percentages, or the same percentages, may be used for other suitable low and high thresholds and for imagers having the same or a different total number of pixels.

FIG. **4** illustrates a timing diagram **200** of an imager frame exposure and illumination pulse sequence with a fixed pulse illumination rate. The top row **205** indicates imager exposure times and the lower row **250** indicates the LED illumination pulse times. The imager exposure time may range from approximately 1 to 10 rows which corresponds to about 26 μs—260 μs. The imager is provided with exposure control depending upon the overall exposure of a particular image, the exposure time of the subsequent image will be adjusted up or down accordingly.

Looking to the rows of imager exposure, the first exposure **202** has an exposure time of 5 rows (about 95 μs). A histogram of the image is analyzed according to the above-described methodology to determine whether an LCD screen is in the field of view. In this instance, the image did not constitute an LCD screen and thus for the second exposure **204**, the reader remains in normal operating mode. The imager may also adapt its exposure time for the second exposure **204** depending upon the results of the first exposure. The second row **250** shows a corresponding illumination pulse for illuminating the field of view. The pulses **252**, **254**, **256**, etc., are fixed length pulses pulsed at a given frequency (60 Hz); pulsed to coincide within the respective image exposures **202**, **204**. At the second image exposure **204**, a histogram indicates by the above process that an LCD screen has been detected in the read region and thus for the next exposure (exposure **206**) the reader switches to LCD reading mode for a cycle of 12 images (four of which are being shown **206**, **208**, **210**, and **212**) with the longer exposure time of 70 rows (corresponding to about 1200 μs). In the LCD reading mode, this longer exposure time is provided to give the reader additional exposure since the illumination LED is off during the LCD reading mode, whereby the LCD is read/illuminated only by ambient light or LCD backlight. At the end of the 12 images taken during the LCD reading mode (or optionally earlier if a label is read

before the 12th image), the reader switches back to normal reading mode at image exposure **214** illuminated by LED pulse **256** and the normal reading process takes over again. Exposure **214** is again a short exposure (1-10 rows) illuminated by LED pulse **256**. The histogram of image **214** shows the image taken is not an LCD screen thus the example proceeds to exposure **216** and remains in standard mode illuminated by LED pulse **258** and again the image exposure **216** indicates an LCD screen is not shown and reader remains in standard mode for the next image exposure **218** illuminated by LED pulse **260**.

The diagrams **200**, **300** of FIGS. **4-5** show exposure times as 5 rows, a middle value for the exposure, but as described herein the exposure time is set in a range of 1-10 rows, 26 μs to 260 μs, depending upon the adaptive exposure setting according to the prior exposure analysis.

As is seen by illumination row **250** in the chart **200**, there is a large gap between illumination pulse **254** and illumination pulse **256**. Depending upon the number of cycles between the standard reading mode with the LED on and the LCD reading mode with the LED off, a perceptible flicker can be visible to the user or others and cause either annoyance or discomfort.

To avoid this annoying flicker, an alternate system with the LED illumination being illuminated during each image exposure cycle is defined. FIG. **5** is a timing diagram **300** illustrating an imager exposure row **305** and LED illumination pulse row **350** corresponding thereto. Conceptually, during standard mode, the LED pulse illuminates during image exposure while during the LCD mode, the illumination pulse is set to follow or be otherwise offset from the exposure (the LED pulse being exposures). In such a process, the time between LED pulses tends to be much smaller, on the order of 55 Hz, which is generally above the frequency of a human eye and therefore is not perceived as the annoying flicker when the reader is switched between standard reading mode and the LCD reading mode.

Turning in more detail to the figure, exposure **302** runs a histogram indicating that an LCD screen is not indicated/detected and then the reader proceeds to remain in the standard mode for the next exposure **304**. LED pulses **352** and **354** must align with each of the respective exposures **302**, **304**. Exposure **304** is analyzed and indicates that the exposure as shown is an LCD screen and for the next image exposure **306** switches to LCD reading mode with a much longer **70** row exposure **306**. The amount of exposures in the LCD mode is preferably a set programmable amount. In this example, a number of 20 exposures is selected. The number of exposures may be preset and fixed for the reader at the point of manufacture, programmable by the user, variable as controlled by a program criteria such as dependent on the LCD mode cycles attempted, or dependent on whether a LCD screen is confirmed by image histogram analysis. Alternately the amount of exposures in the LCD mode may be controlled via a timer, for example the timer permitting exposures for a set time (e.g., 0.5 seconds, the timer being operative for measuring or counting down the given time for LCD mode capture/read attempts), that time being set at point of manufacture, programmable by user, variable as controlled by a program criteria.

The LCD mode exposure time is shown as a fixed time (70 rows=about 1280 μs), but may be longer or shorter (for example 50 rows to 100 rows) with Automatic Exposure Control on. The LCD mode exposure time may be preset and fixed for the reader at the time of manufacture, programmable by the user, or variable as controlled by a program criteria such as adapted based upon feedback from the previous exposure. The LCD mode exposure time (on the order of 50-100 rows) is much longer that the standard mode exposure time (1-10 rows) and thus is on the order of 10 times or more (5× to 100×) longer.

The LED pulse **356** is intentionally offset and outside of the imager exposure **306**. Similarly, the LED pulses **358**, **360**, and **362** are outside of their respective exposures **308**, **310**, **312**. Thus during the LCD reading mode, the exposures are illuminated only by ambient light and LCD display backlight if LCD display is in scan volume because the LED illumination pulses are offset or otherwise between consecutive image exposures. If an optical code is successfully read (one or more times as required) during the LCD reading mode, the reader exits the LCD reading mode (acknowledging with a good read signal and reporting/transmitting the code) and returns to standard reading mode looking for a subsequent barcode. The processor/decoder includes suitable two-label reading prevention schemes.

If no barcode is successfully read after given number of cycles (e.g., the 20 cycles) in the LCD reading mode, the system returns to standard reading mode, and proceeds to image exposure **314** which is illuminated by LED pulse **364**. Image exposure **314** has its histogram analyzed and in this example it is determined that an LCD screen is not present and for the subsequent image exposure **316** the reader remains in the standard mode illuminated by LED pulse **366** (the pulse occurring during or overlapping the exposure **316**. At image exposure **316**, it is again determined that an LCD screen is detected and thus for the subsequent **20** exposures **318-320**, the reader switches to LCD reading mode with LED pulses **368-370** offset from the respective image exposures as previously described. After the 20 cycles (or optionally immediately if a barcode is successfully read) the reader returns to standard reading mode at image exposures **322**, **324**, **326** illuminated by respective LED pulses **372**, **374**, **376** as previously described.

FIG. **6** (comprised of FIGS. **7** and **8**) is a flow chart of a method **400** according to one embodiment, the method comprising the following steps, the steps typically being performed via a processor contained in electronic circuitry of the data reader:

At Step **402**—Start.

At Step **404**—In standard mode, pulsing illumination and performing exposure (capturing an image or set of images) at standard mode exposure time during illumination. Illumination may comprise an LED pulse, the exposure is timed such that the LED pulse is within or overlaps with the exposure. Exposure time for the first exposure may be preset (e.g., 5 rows), programmable, or may be set to the last exposure previously taken.

At Step **408**—Processing exposure image(s) for detecting and reading optical code.

At Step **410**—Determining if an optical code has been read successfully. If Yes a code has been read successfully, proceeding to Step **412** to report a good read, and if No proceeding to Step **416**.

At Step **412**—From the Yes condition in Step **410**, reporting a good read of the optical code and then proceeding to Step **404**.

At Step **416**—From the No condition in Step **410**, analyzing a histogram of the exposure and determining if the exposure was of an LCD screen; if No proceeding to Step **420**, and if Yes proceeding to Step **426**.

At Step **420**—Analyzing intensity of the image and adjusting exposure time for the next image exposure.

At Step **422**—Illuminating field and performing next exposure at the adjusted exposure time (from Step **420**); then returning to Step **408**.

At Step **426**—From the Yes condition in Step **416**, resetting number of LCD mode exposure attempts (n=1).

At Step **430**—Performing exposure at LCD mode exposure time, and pulsing illumination outside of the exposure. The LCD mode exposure time is larger (e.g., 70 rows) since exposure is via ambient illumination. The LED illumination is still pulsed, but occurs after exposure so that the illumination does not interfere with the ambient illumination reading during the LCD mode exposure.

At Step **434**—Processing exposure image for detecting and reading an optical code.

At Step **436**—Determining whether an optical code has been read successfully. If Yes proceeding to Step **438** for reporting a good read; if No proceeding to Step **440**.

At Step **438**—From the Yes condition in Step **436**, reporting a good read and then returning to Step **404**.

At Step **440**—From the No condition in Step **436**, determining whether the number of attempts to read/exposures in the LCD mode has reached the given maximum (is n≥20). If Yes, return to Step **404** (to switch back to standard mode) and if No, proceed to Step **444**.

At Step **444**—Incrementing n (n=n+1); proceed to Step **430** to perform a subsequent exposure in the LCD mode.

The method **400** may include additional steps and features, and certain steps may be omitted, and certain steps may be combined. For example as to omitting a step, Step **420** may be omitted and the exposure time may be constant or be varied by a set pattern rather than being adaptive. For example as to adding steps, an optical code portion acquired in one image may be combined with another optical code portion from another image and thus be assembled into a complete optical code, the process being generally known as stitching. For example as to combined steps, Step **416** may be omitted and combined with Step **404** whereby Step **420** proceeds directly to Step **404** (instead of Step **408**) and the exposure time (in Step **404**) would be set in accordance with Step **420**. Though a given sequence of steps in method **400** is described, certain of the steps may be undertaken in other/different sequences. For example, the incrementation in Step **444** and the resetting of Step **426** may be undertaken at any suitable time; in another example, the intensity analysis of Step **420** may be undertaken before Step **410** or in conjunction with Step **408**.

FIG. **9** is a flow chart of a program algorithm **500** for data reading of an optical code being displayed on an electronic display according to another embodiment, comprising the following steps:

At Step **502**—Start.

At Step **504**—Read control parameters. These control parameters for an initial read may be preset in the software/firmware or programmable, but once the system is operating, the parameters correspond to the parameters set by the prior image captured.

At Step **506**—Determining if an LCD screen has been detected in the prior image exposure as set forth in the updated control parameters (as will be explained below with respect to Steps **514** and **534**). If NO proceed to Step **530** (standard mode with illumination) and if YES proceed to Step **508** (LCD mode without LED illumination). In a preferred implementation, the system actually processes several images and analyzes a plurality of images rather than a single image when making decisions. In one configuration, the system requires multiple frames/exposure (e.g., five consecutive frames) satisfying the LCD screen detection condition before switching to LCD mode.

At Step **530**—With no LCD detected from Step **506**, setting Automatic Exposure Control/Automatic Gain Control (AEC/AGC) to setting **1** with normal exposure at 1 to 9 rows and illuminated by the LED pulse during exposure.

At Step **531**—Setting decoding parameters. These parameters may include how long to spend on 2D label decoding, how long to spend on 1D decoding, selection of symbology decoding order (which one is first, which one is last, etc.), and other typical decoding parameters. The decode parameters set at Step **531** may be programmable and are preferably suited for the standard mode (illuminated) reading.

At Step **532**—Capture image of the field of view.

At Step **534**—Performing image histogram analysis (to determine whether an LCD screen has been detected) and updating control parameters for the next exposure (e.g., analyzing intensity of the image and adjusting exposure time for the next image exposure).

At Step **536**—Decoding the image.

At Step **538**—Determining if an optical code has been read successfully. If YES a code has been read successfully, proceeding to Step **540** to report a good read, and if NO proceeding back to Step **504**.

At Step **550**—From the YES condition either Step **538** or Step **520**, reporting a good read of the optical code and then proceeding to Step **504**.

Turning to Step **508**—From the YES condition in Step **506**, wherein an LCD was detected from Step **506**, setting Automatic Exposure Control/Automatic Gain Control (AEC/AGC) to setting **2** (LCD screen mode) with longer exposure at 70 rows (for example) and not illuminated by the LED pulse during exposure, the LED illumination pulse being shifted outside of the exposure. The LCD mode exposure time is longer (e.g., 70 rows) since exposure is via ambient illumination (including the backlighting from the LCD). The LED illumination is still pulsed, but occurs outside exposure so that the illumination does not interfere with the ambient illumination reading during the LCD mode exposure.

At Step **510**—Setting decoding parameters. These parameters may include how long to spend on 2D label decoding, how long to spend on 1D decoding, selection of symbology decoding order (which one is first, which one is last, etc.), and other typical decoding parameters. The decode parameters set at Step **510** may be programmable and are preferably suited for the LCD mode (non-illuminated) reading.

At Step **512**—Capture image of the field of view.

At Step **514**—Performing image histogram analysis (to determine whether an LCD screen has been detected) and updating control parameters for the next exposure (e.g., analyzing intensity of the image and adjusting exposure time for the next image exposure).

At Step **516**—Decoding the image.

At Step **520**—Determining if an optical code has been read successfully. If YES a code has been read successfully, proceeding to Step **540** to report a good read, and if NO proceeding to Step **541**.

At Step **541**, determining if presence of an LCD screen is confirmed. If Yes proceed to Step **522**, if No proceed to Step **523** for exiting LCD mode, updating control parameters and returning to Step **504**.

At Step **522**—From the Yes condition in Step **541**, determining if the counter of given number of frames (image exposures) has been attempted (e.g. 12 frames), namely that the counter has expired. If YES, proceed to Step **523** for exiting LCD mode, updating control parameters, and returning to Step **504** and if NO proceeding to Step **524**.

At Step **524**—From the NO condition in Step **522**, counting down/decrementing the counter (n=n−1) for the number of LCD mode exposure attempts remaining, then returning to Step **508** for another exposure in LCD screen mode.

The method **500** may include additional steps and features, and certain steps may be omitted, and certain steps may be combined. For example as to omitting a step, portions of Step **530** may be omitted and the exposure time may be constant or be varied by a set pattern rather than being adaptive. In another example, Step **514** may be omitted with exposure and other parameters being constant in the LCD mode, with parameters resetting to standard mode following Step **522** YES condition. For example as to adding steps, an optical code portion acquired in one image may be combined with another optical code portion from another image and thus be assembled into a complete optical code, the process being generally known as stitching. Another additional step may be an optional reset step after Step **522** following the YES condition whereby the control parameters are updated/reset to standard mode. Though a given sequence of steps in method **500** is described, certain of the steps may be undertaken in other/different sequences. For example, the decrementation in Step **524** may be undertaken at any suitable time; in another example, the decode image Step **536** may be undertaken before Step **534**.

While certain preferred systems and methods have been shown and described, it will be apparent to one skilled in the art that modifications, alternatives and variations are possible without departing from the inventive concepts set forth herein. Therefore, the invention is intended to embrace all such modifications, alternatives and variations.

The invention claimed is:

1. A method for data reading of an optical code being displayed on an electronic display, comprising the steps of:

(1) in standard reading mode, illuminating the field of view with one or more pulses of illumination;

(2) capturing, via a data reader, a first two-dimensional image (or set of images) of the field of view being illuminated by the one or more pulses, in search of an optical code appearing therein;

(3) processing the first image(s) in an attempt to decode the optical code;

(4) analyzing the first image(s), that was/were captured while the field of view was being illuminated by the one or more pulses produced by at least one source of illumination, to determine whether an electronic display is in the field of view;

(5) if it is determined, in step **4**, that an electronic display is in the field of view, switching to electronic display reading mode;

(6) in electronic display reading mode, for up to a given amount of second image capture/read attempts, capturing, via the data reader, a second two-dimensional image (or set of images) of the field of view without illumination from the one or more pulses, in search of an optical code appearing therein;

(7) illuminating the field of view with one or more pulses of illumination at least one or both of before and after each second image capture/read attempt;

(8) processing the second image(s) in an attempt to decode the optical code.

2. A method according to claim **1** wherein the given amount of second image capture/read attempts is selected from the group consisting of: (a) a given plurality of second image capture/read attempts, (b) a given number of second image read or capture cycles, (c) a given time for second image capture/read attempts.

3. A method according to claim **1** further comprising

if it is determined that an electronic display is not in the field of view, remaining in standard reading mode, and performing an exposure analysis of the first image(s) and adjusting exposure time for a subsequent image exposure.

4. A method according to claim **1** further comprising setting an exposure time during the electronic display reading mode at a longer time exposure than that of the standard mode exposure time.

5. A method according to claim **1** wherein the given amount of second image capture/read attempts is a given plurality of second image capture/read attempts, wherein the given plurality of second image capture/read attempts comprises on the order of 20 attempts.

6. A method according to claim **1** wherein the step of analyzing the first image(s) to determine whether an electronic display is in the field of view, comprises

analyzing a histogram of the first image(s) to determine whether the histogram is bi-modal;

automatically adjusting operating parameters of the data reader based on whether the histogram is bi-modal;

capturing, via the data reader, a second image(s) of the item bearing the optical code using the adjusted operating parameters; and

processing the second set of images to decode the optical code appearing in the second image(s) of the item.

7. A method according to claim **6**, wherein analyzing the histogram to determine whether the histogram is bi-modal includes:

comparing a first number of pixels against a predetermined grayscale low threshold percentage; and

comparing a second number of pixels against a predetermined grayscale high threshold percentage.

8. A method according to claim **1** further comprising

determining whether the electronic display is backlit; and

adjusting operating parameters of an imager of the data reader based on whether the display screen is determined to be backlit.

9. A system for data reading comprising:

an imager for capturing an image of an item bearing an optical code;

an illumination source for illuminating the item; and

a controller for operating the imager and the illumination source, wherein the controller is programmed to,

operate the imager to capture a first two-dimensional image (or set of first images) of the item being illuminated by the illumination source;

analyze the first image(s) to determine whether the item is likely to comprise an electronic display screen;

if determined that the item is likely to comprise an electronic display screen, for up to a given amount of second image capture/read attempts, operate the imager (a) to capture a second two-dimensional image(s) of the item without illumination from the illumination source, and (b) to illuminate the field of view with a pulse of illumination at least one or both of before and after each of the second image capture/read attempts.

10. A system for data reading according to claim **9** wherein the given amount of second image capture/read attempts is selected from the group consisting of: (1) a given plurality of second image capture/read attempts, (2) a given number of second image read or capture cycles, (3) a given time for second image capture/read attempts.

11. A system for data reading according to claim **9** further comprising a timer, wherein the given amount of second image capture/read attempts is a given time for second image capture/read attempts, wherein the timer is operative for measuring or counting down the given time for second image capture/read attempts.

12. A system for data reading according to claim 9 wherein if determined that the item is likely to comprise an electronic display screen, for up to a given amount of image capture/read attempts, the controller is further programmed to (c) operate the imager to capture a second two-dimensional image(s) of the item without illumination from the illumination source and using alternate operating parameters.

13. A system for data reading according to claim 12, wherein the alternate operating parameters in the capture/read attempts of the second image comprises exposure time for image capture.

14. A system for data reading according to claim 12, wherein the controller is further programmed to adjust operating parameters of the imager based on whether the display screen is backlit.

15. A method for data reading comprising:

with an imager, capturing an image of an item bearing an optical code;

illuminating the item via at least one illumination source; and

controlling operation of the imager and the illumination source by

operating the imager to capture a first two-dimensional image (or set of images) of the item being illuminated by the illumination source,

analyzing the first image(s) to determine whether the item is likely to comprise an electronic display screen;

if determined that the item is likely to comprise an electronic display screen, for up to a given amount of image capture/read attempts, (a) operating the imager to capture a second two-dimensional image(s) of the item without illumination from the illumination source, and (b) illuminating the field of view with a pulse of illumination at least one or both of before and after the capture/read attempts.

16. A method for data reading according to claim 15 wherein the given amount of second image capture/read attempts is selected from the group consisting of: (1) a given plurality of second image capture/read attempts, (2) a given number of second image read or capture cycles, (3) a given time for second image capture/read attempts.

17. A method for data reading according to claim 15 further comprising via a timer, measuring or counting down a given time for second image capture/read attempts, wherein the given amount of second image capture/read attempts corresponds to a given time for second image capture/read attempts.

18. A method for data reading according to claim 15 wherein if determined that the item is likely to comprise an electronic display screen, for up to a given amount of image capture/read attempts, (c) operating the imager to capture second two-dimensional image(s) of the item without illumination from the illumination source and using alternate operating parameters.

19. A method for data reading according to claim 18, wherein the alternate operating parameters in the capture/read attempts of the second image comprises exposure time for image capture.

20. A method for data reading according to claim 18, further comprising adjusting operating parameters of the imager based on whether the display screen is backlit.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,122,939 B2
APPLICATION NO. : 13/204627
DATED : September 1, 2015
INVENTOR(S) : WenLiang Gao and Craig D. Cherry

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the specification

Column 3
Line 8, after "may" insert --be--.

Column 4
Line 9, after "imager" delete "by".
Line 43, after "memory" insert --that--.

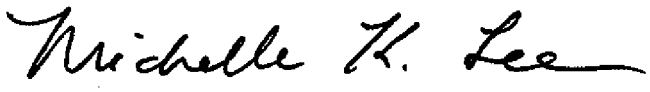
Column 5
Line 34, change "may" to --may be--.

Column 8
Line 1, change "that" to --than--.
Line 26-27, change "366 (the" to --366, the--.

Column 10
Line 52, before "step 540" insert --step 521 (exit LCD mode: update control parameters) and then proceeding to--.

Column 12
Line 42, change "programmed to," to --programmed to--.

Signed and Sealed this
Eleventh Day of October, 2016



Michelle K. Lee
Director of the United States Patent and Trademark Office